PHYSICAL ELECTRONICS
A DIVISION OF ULVAC-PHI

Mapping Motor Oil Additives on a Cam Shaft Lobe with PHI Scanning XPS Microprobes

Introduction

The wear resistance of internal combustion engine parts can be improved by using appropriate motor oil additives. Extreme pressure and temperature conditions exist in areas where moving parts are in contact. These conditions will cause the molecular structure of properly chosen additives to break down and result in the formation of wear resistant surface compounds (iron phosphates and sulfides are typical). The chemistry and spatial distribution of such surface compounds can be probed with x-ray photoelectron spectroscopy (XPS/ESCA)

Macro Area Analysis

A PHI *Quantera* II Scanning XPS Microprobe was used to examine the nose of a cam shaft lobe removed from an engine operated with a fluorocarbon (PTFE*) motor oil additive.[1] Fluorine was detected and was found to be concentrated in the wear track of the cam lobe.

The F 1s binding energy indicated that the fluorine was in a metal fluoride state demonstrating a conversion from the original fluorocarbon form. For the analysis, the lobe was cut from the cast iron cam shaft without using a cutting lubricant (which might interfere with the analysis). Sectioning of the hardened steel lobe, which would have required cooling fluid, was not necessary due to the capability of the *Quantera* II to handle large samples.

Automated acquisition of spectra from 125 analysis areas (1.5 mm X 0.4 mm each) within the highlighted region of Figure 2 was carried out using the instrument control software. Using PHI Multipak™ data reduction software, all 125 spectra were simultaneously processed to generate the quantified elemental maps shown in Figure 3. The elements considered (C, O, Zn and F) made up more than 90 atomic per cent of the surface within the depth probed by XPS (~ 50 Å). Other low level elements (Fe, S, P) were neglected here since F was the focus of this study.

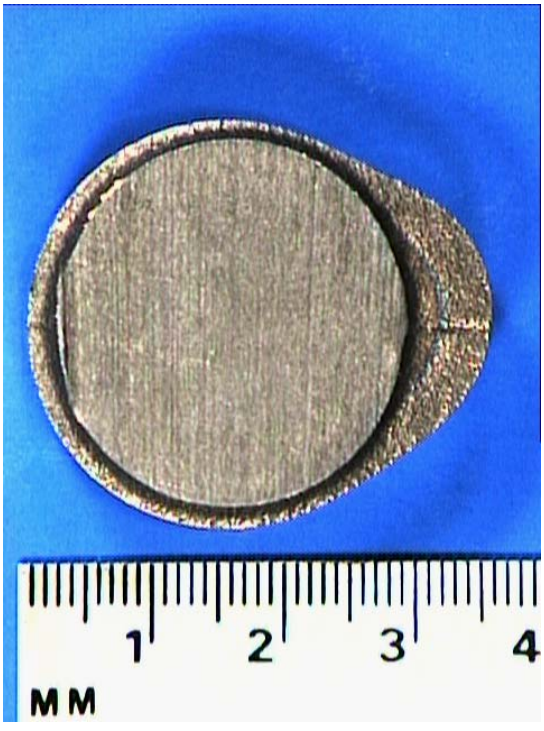

Figure 1. Side view of cam lobe. Note the circular cross section of the cam shaft.

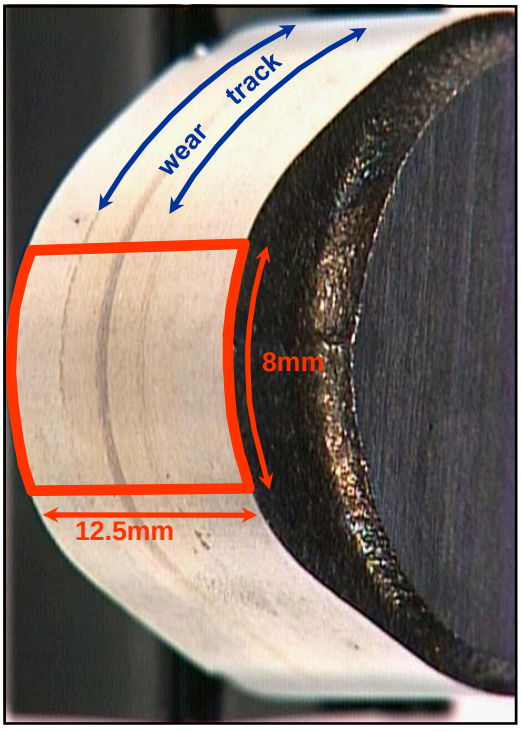

Figure 2. Oblique view of cam lobe illustrating the analysis area for the chemical maps in Fig. 3.

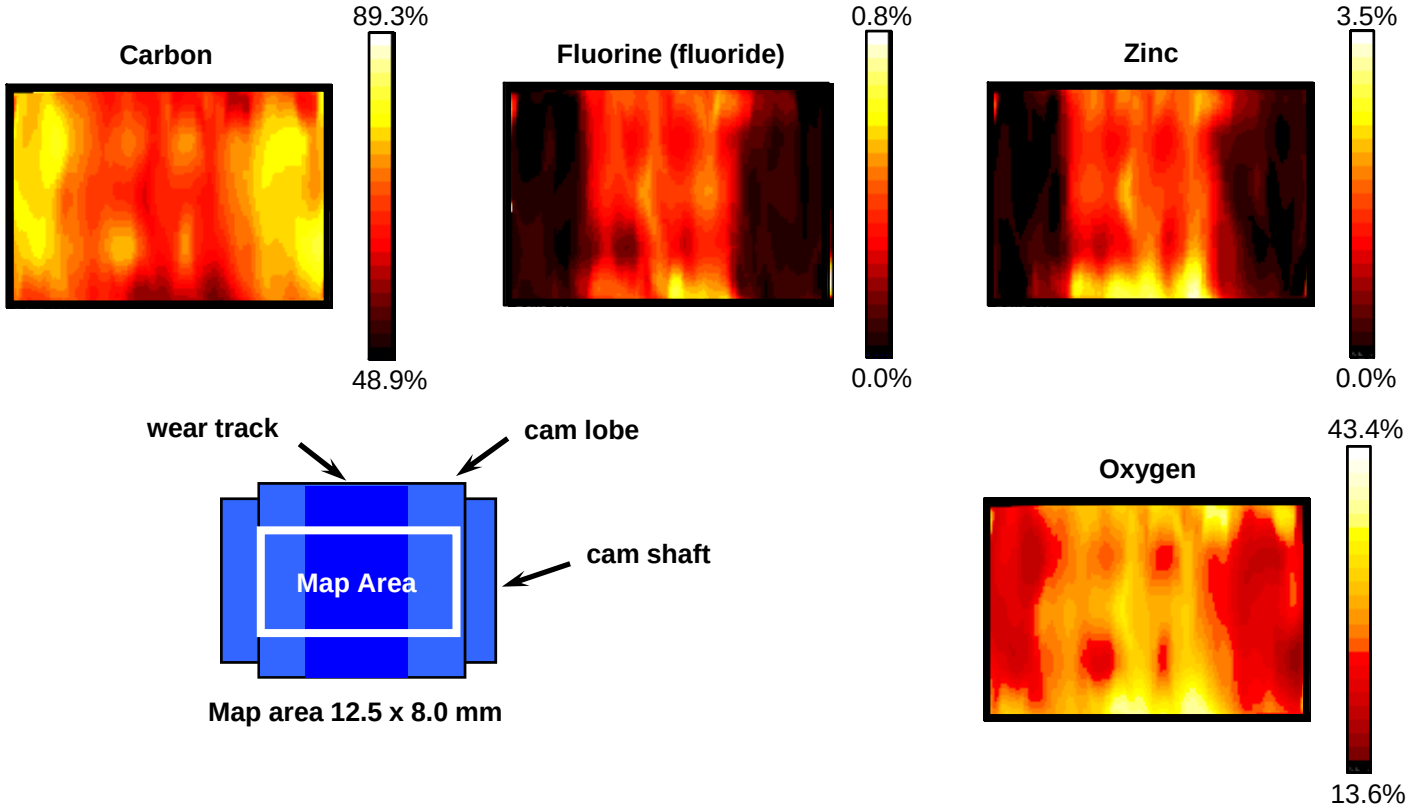

Figure 3. Elemental maps of the cam lobe surface quantified in atomic %. The wear track runs vertically through the images as illustrated in the schematic view of the cam lobe. The maps show fine structure within the wear track corresponding to the three sub-tracks visible in Fig. 2.

In addition to the fluorocarbon additive, a typical motor oil additive containing zinc, sulfur, and phosphorous (ZDDP†) was also present in the oil. The presence of fluoride and zinc within the wear track indicate that the additives have reacted with the steel surface of the cam lobe under the influence of heat and pressure. The F may contribute to wear resistance while Zn (as an oxide) is believed to be present as an inconsequential reaction product. Sulfur and phosphorus from the ZDDP additive were also observed in point spectra within the wear track but were absent outside the wear track. Thus, additive components were not detected where conditions were not favorable for reaction.

This work has demonstrated the ability of the *Quantera* II to obtain quantitative elemental maps from the surface of a large, irregularly shaped object. In this case, the data show that motor oil additives formed reaction products in areas subject to wear.

[1] See SAE Paper 982440, October 1998, for a complete description of the experiment.
* PTFE - poly(tetrafluoroethylene) also known as Teflon® (registered trademark of DuPont)
† ZDDP - zinc dialkyldithiophosphate

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